STRUCTURES OF BASIN RANGES

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Several memoirs recently published have awakened a new interest in the geotectonics of the Great Basin region. The main structural features about which discussion centers appears to be whether the Basin ranges are the result of normal faulting and form "block" mountains; or whether the "block" aspect is only apparent, in reality the "block" originally being a sharp asymmetric fold, in which subsequent erosion wears off the steeper limb faster than the other.

In the elucidation of the arguments by specific example, it is unfortunate that some of the illustrations selected have not been chosen with greater discernment. It is now well understood that some of the instances noted furnish the most conclusive proofs of directly the contrary of the purpose for which they were cited. Without entering into detail in regard to many of these cited examples from other parts of the Basin region, it seems pertinent at this time to call attention briefly to certain features displayed in the New Mexican part of the field. These may help to explain similar phenomena in other districts.

The geologic sequence in central New Mexico is especially noteworthy on account of the almost complete absence of the Lower Paleozoic rocks and the enormous development of the Cenozoic strata. The important member of the sequence above the Proterozoic metamorphics is the Upper Carboniferous limestone which attains a normal thickness of 2,000 feet.

In all of the mountain ranges of central New Mexico, appearing as tilted blocks, the crests of which rise 3,000–5,000 feet above the bases, the great Carboniferous limestone forms the backslope, usually reaching to the summit. On the opposite or steep face of the ridges the Proterozoic clastics and schists, which usually stand on edge, are exposed for a vertical distance of 2,000 feet, or more. Above the Carboniferous limestones at the foot of the mountains are Red Beds and then Cretaceous sandstones.

No evidence has yet been found that would indicate that any of these numerous mountain blocks were produced by folding. All observations go to show most conclusively that only faulting is involved. The sedimentaries of some of these mountains, however, are often folded and closely corrugated. Thrust-planes are plainly visible. Numerous other indications point to tremendous compression at some time or other. But the period of compressive action has been found to be a very different one from that during which the present mountains were formed. The compression took place long before the existing mountain blocks reared their heads above the

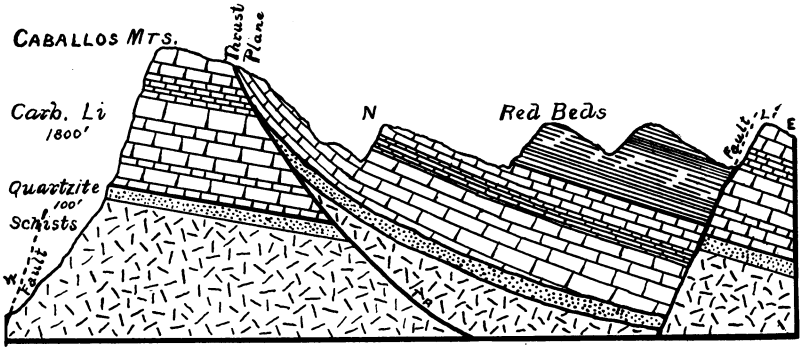

FIG. 1

vast surrounding plains. Chronologically this period of compressive conditions was manifestly after the Carboniferous, because the rocks of this age were involved; but it was before the late Cretaceous, since Cretaceous strata are as clearly not affected.

In the Sierra de los Caballos, in south-central New Mexico, the geological sections are particularly instructive. Near the highest point of the range, known as Timber Peak, the scarp is over 3,000 feet high and displays an excellent exposure of the rocks throughout this entire vertical distance. The transverse section shown a short distance to the north is represented in the diagram, Fig. 1. The heavy line *T. P.* indicates the position of an exceedingly well-displayed thrust-plane. Along it the beds are highly contorted. The entire limestone is badly shattered and traversed by large and small crevices which are now cemented by calc-spar. The inclination of the thrust-plane is now rather steep, but, as will appear subsequently,

this is due partly to the fact that the present position of this structure is not the original one. Since its formation the thrust-plane also has been tilted in marked degree. In point of time, the formation of the thrust-plane long antedates the uprising of the present mountain blocks.

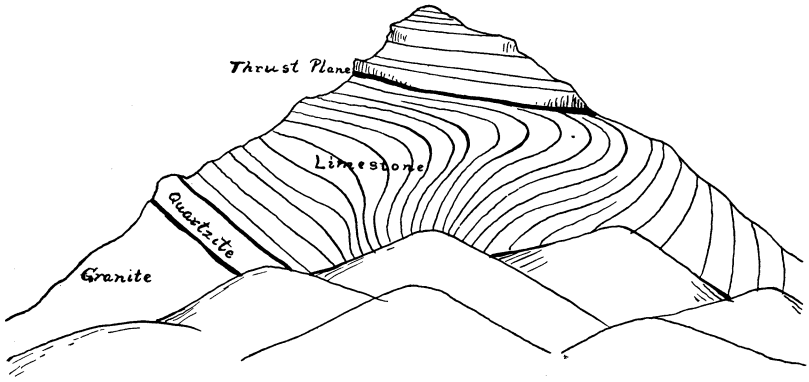

FIG. 2

A few miles to the north, in the same range, is another lofty point called Caballo Peak. There are clearly shown in this place the limestone beds completely overriding the lower beds, the first mentioned now reposing nearly horizontally on inclined strata. Fig. 2 is a sketch of the peak as it appears from the south.

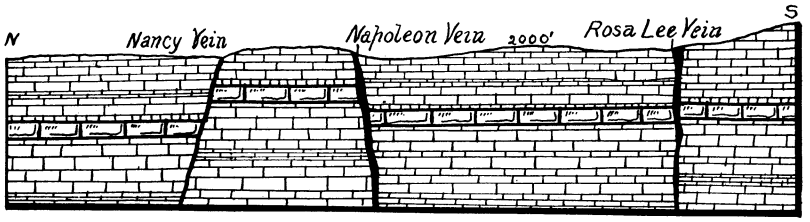

FIG. 3

Another system of faults, the age of which is quite recent, also exists. These dislocations run transverse to the other two and to the axis of the range. As they appear in the canyon walls (at *N*, Fig. 1), a sketch of them (Fig. 3) is annexed.

There are, then, in the Sierra de los Caballos at least three very distinct periods of faulting. The first was before the formation of

the present mountain ridge; a second was coeval with its formation; and the third was long subsequent to its uprising.

Were it not for exceptionally clear evidence to the contrary, casual examination could very easily lead to the conclusion that the Caballos mountain range was produced by sharp folding and that the crest of this asymmetric fold was removed through erosion. This deduction is a quite natural one, especially when, in a view from the summit of the range, there are clearly shown the strata dipping eastward forming a broad syncline and coming up again with westerly dips in the great San Andreas Mountain block, 30 miles beyond.

It so happens that in the instance under consideration we now know enough of the general geological history of the region to give us a good insight into some of the actual conditions that have existed. It has recently been shown[1] that the Upper Cretaceous of central New Mexico rests in marked unconformity upon the older rocks. The period during which conditions existed for folding of the strata was, already stated, later than the laying down of the Carboniferous limestones and later than the deposition of the "Red Beds," as these were all involved.

A number of observations lately made emphasize the character of the events which took place in the region during early Cretaceous times, and the great importance of the unconformity at the base of the Cretaceous of the region. That during this period the older rocks were greatly disturbed over wide areas is amply attested by the almost vertical "Red Beds" (Carbo-Triassic) overlain by horizontal Cretaceous, as is seen at Tejon, south of Santa Fé, in Sandoval county;[2] the highly inclined Carboniferous limestones, on either side of high trachyte dikes on which recline nearly horizontal Cretaceous sandstones on the Chupadera Mesa, in eastern Socorro county;[3] and the position of the Cretaceous on the older formations in the Caballos Mountains in Sierra county; as well as in other localities. The unconformity represents a great land surface; and during the interval for which it stands the strata of the region were folded and eroded off to a plain-like surface before being later covered by sediments.

[1] *American Journal of Science* (4), Vol. XVIII (1904), pp. 356–58.

[2] *Ibid.*, p. 357.

[3] *Ibid.*, p. 358.

Attention is especially called to these facts for the reason that in some instances cited relative to the structure of Basin ranges it is quite manifest that the proper local interpretations have not been made. It is probable that a large number of other cases will be found to be illy chosen for purposes of type illustration. The observations made in the Sierra de los Caballos are suggestive of similar phenomena occurring in other districts. Critical evidence on the points emphasized is much desired from many other ranges. When once secured, it may do much towards correcting some very erroneous present interpretations.

A generalized geological cross-section of a part of the Basin region of New Mexico more clearly illustrates the type of mountain structure under consideration (Fig. 4).

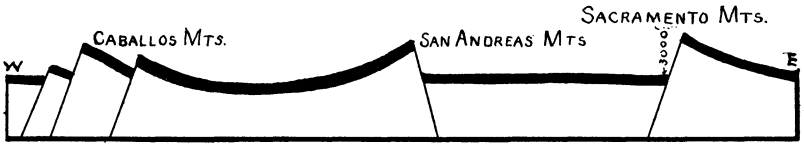

FIG. 4

In all of these ranges there are abundant evidences of marked compression producing the phenomena of folding and thrusting. Yet in every instance thus far observed the period of this movement is found to be long prior to the elevation of the present mountains.

There is another very deceptive feature connected with the formation of the block-like mountains of the New Mexican portion of the Basin region. At the foot of the steeper slope the strata are often found tilted at a high angle, and inclined away from the range. The attitude of the beds easily suggests, at first consideration, the possibility of the mountain ridges being a sharp anticline, with the center completely removed through erosion, leaving the limbs of the arch unequally exposed. This condition might be readily fancied because of the fact that the greater part of the height of the mountains, 3,000–4,000 feet, is usually composed of massive crystallines and schists, and the crest and backslope of the limestones.

There are strong reasons for believing that this phenomenon, instead of being ascribed to folding of the asymmetrical type, should be considered an accompaniment of normal faulting. Only the

faulting is on a gigantic scale—a scale very much larger than is usually met with. When the hade is steep, the strata on the down-throw side to a greater or less degree commonly lag, until a considerable zone is produced in which the strata become highly inclined, and in many cases stand even nearly vertically. A typical case is represented below:

In a smaller way we find the same lagging structures accompanying the faulting in coal mines. It is a fact well known to the miners that when the dip lessens a down-slip is soon to be expected.

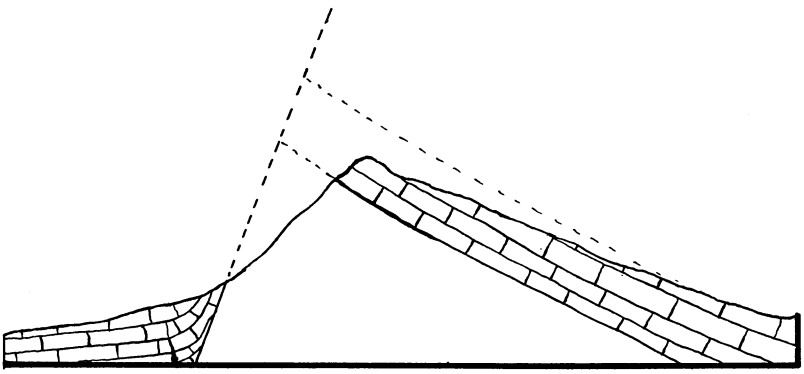

FIG. 5

There is a theoretical reason for believing that in the region under consideration normal faulting, instead of folding, is to be expected to explain the origin of the New Mexican mountains of the Basin district. The principle was clearly set forth by LeConte[1] as long ago as 1889, when discussing the Nevada region between the Sierra Nevada and the Wasatch Mountains.

As considered there and in his textbook of geology[2] this author appears to have regarded the area in question as a region which was subjected to slow and general uprising, but continually adjusting itself through normal faulting in great blocks. By the tilting which these blocks suffered mountain ranges were produced on the elevated edge, and on the depressed side were formed valleys which were subsequently filled with sediments.

[1] *American Journal of Science* (4), Vol. XXXVIII (1889), p. 259.

[2] *Elements of Geology*, 5th ed. (1904), p. 242.

In the late account of the Humboldt region in Nevada, Lauterback[1] dissents somewhat from the view of the simple tilted block idea, and is inclined to believe that the mountain-block and the valley-block are distinct. This appears often to be the correct interpretation in the New Mexican part of the Basin region.

The physiographic development of the New Mexican region appears, briefly to be as follows: About the beginning of Tertiary time the area lying between what is now the Gulf of California and the Gulf of Mexico must have been a vast low-land plain elevated but slightly above sea-level, and having faint relief features. A large part of the plain was a surface worn out on the beveled edges of Cretaceous and older strata, as is, even at the present day, still clearly discernible in its remnants. The Las Vegas plateau, the Llano Estacado, the bolson plains of central New Mexico, and some of the less-broken plains of eastern Arizona appear to belong genetically together. To the east and west of the vast area thus outlined there had been formed, from the sediments derived from the planing off of the central land area, a broad submarine platform. When later in Tertiary times the general bowing up of the region began to take place, the great plain that had been formed was partly a peneplain of destructional land origin and partly a constructional plain of marine origin.

During the period of uprising folds were extensively developed, and the compression was so intense that in many cases thrust-faults were formed. Many low mountain ridges were probably produced at this time. Subsequently, as if the upward movement had been too extensive, the compressive force gave way to one of tension. Normal faulting on a grand scale occurred, producing the numerous short monoclinal or "block" mountains of the region.

Several important points bearing upon Basin Range structures appear to be reached in the present connection:

1. The determination of the most obvious structures of any particular mountain region is not sufficient and is not critical evidence; the time of the formation of the structures is an all-important consideration. When the younger strata are removed from the mountains, the structures of the older rocks may tell a very different story. In some

[1] *Bulletin of the Geological Society of America*, Vol. XV (1904), p. 343.

instances mentioned by Spurr the younger strata would seem to be entirely wanting. In many New Mexico ranges the great Carboniferous limestones form the major portion, and they give evidence of an older and very different record of events from that which includes the uprising of the present mountain blocks.

2. The structures of each mountain range must be determined separately and upon the evidence which it alone presents. Even in neighboring ranges one may disclose a history very much longer and older than another.

3. In the New Mexico area orogenic movement, while more or less rhythmic in character, was doubtless continuous since Paleozoic times. At least three periods of marked activity have been recognized.

4. Modern ranges, the "block" mountains rising out of the Basin plains, in which the Mesozoic strata are eroded from the summits, are likely to have the structures of the first period of orogenic movement (early Cretaceous) most in evidence, and the later effects may be less strongly emphasized. In the specific cases of New Mexico this period was one of folding and overthrusting.

6. Modern mountains, around which there are late lava flows, are likely to show the effects of the third (Pleistocene) movements. These are chiefly normal faulting.